Advanced Battery Readiness
Ad Hoc Working Group Meeting

March 22-23, 2000
Wyndham Washington Hotel
Washington, DC

Executive Summary

Prepared by the National Renewable Energy Laboratory,
A National Laboratory of the U.S. Department of Energy,
Managed by Midwest Research Institute, Battelle, and Bechtel
Under Contract No. DE-AC36-83CH10093

Table of Contents

	Page
General Session	2
Executive Committee: Summary of Action Items	26

Advanced Battery Readiness Ad Hoc Working Group Meeting

March 22-23, 2000
Wyndham Washington Hotel
Washington, DC

General Session

Introduction
Carol Hammel
Chairperson, Advanced Battery Readiness Ad Hoc Working Group

The Advanced Battery Readiness Ad Hoc Working Group (ABRWG) met at the Wyndham Washington Hotel in Washington, D.C., on March 22-23, 2000. Carol Hammel, Chairperson, opened the general session and welcomed the attendees. She indicated that the focus of the ABRWG is to receive inputs from all the participants, including original equipment manufacturers, battery manufacturers and recyclers, in relation to shipping, recycling, and in-vehicle safety of advanced batteries. She thanked the sponsors of meeting, Dr. Ken Heitner and Mr. Ray Sutula, U.S. Department of Energy (DOE) for their funding support. She then introduced Dr. Heitner, DOE Program Manager and Executive Committee Chairman.

"U.S. DOE Program Overview and Directions,"
Dr. Ken Heitner
DOE Program Manager and Executive Committee Chairman

Dr. Heitner started with a brief overview of where we are in the areas of electric vehicles (EV), hybrid electric vehicles (HEV), and advanced batteries. He stated that hybrid vehicles are now clearly in the market: Toyota Prius and Honda Insight. Both use nickel metal hydride (NiMH) batteries. Other original equipment manufacturers (OEMs) have shown prototype power assist hybrid vehicles. They may be introduced soon to meet the California Air Resources Board's (CARB's) zero-emission vehicle (ZEV) program requirements.

There were over 3250 EVs in use by year-end 1999. About one third use NiMH batteries; about one percent (Nissan only) use lithium-ion batteries.

CARB will review the ZEV requirements later this year, which may affect the 2003 requirements. Developments in other states (New York, Texas, Massachusetts, Maine, and Vermont) may also influence the introduction of EVs and advanced batteries.

Dr. Heitner then turned to the three Subworking Group areas. In shipping, small NiMH batteries for the consumer market have been shipped routinely without problems. The United Nations (UN) Recommendations are the international basis for shipping approval

of large lithium batteries. They were completed in December 1998, and become effective in 2001. In the interim, exceptions must be granted on the basis of this UN Recommendation. Overall, shipping issues are nearly resolved. Details are being worked out, focusing on "T test" requirements, which form the basis for shipping safety self certification.

In the in-vehicle safety area, the status is about the same as last year. There are recommended practices on building EV and HEV and the associated battery systems to assure a high level of abuse tolerance, as specified in SAE Recommended Practice J2464. J2464 evolved from the abuse tolerance evaluation methods for lithium ion EV and HEV batteries developed by the Lithium Battery Energy Storage Technology Research Association (LIBES) in Japan, the European Union Council for Automotive Research (EUCAR), and the United States Advanced Battery Consortium (USABC). We need to review what others are doing and what still needs to be done.

A Sandia Laboratory/USABC report about abuse testing is also widely available.

National Highway Transportation Safety Administration (NHTSA) is proceeding with rulemaking (FMVSS Safety Standard #305), based on SAE J1766 (Battery Systems Integrity Crash Testing). The approach emphasizes limiting electrolyte spillage, assurance of battery retention, and maintenance of electrical isolation of high voltage systems.

NHTSA is also planning to report to DOE on accidents involving electric vehicles. Other information will be obtained as available from Japan on accident experience with the widely-deployed Toyota Prius hybrid vehicle.

United Laboratories (UL), National Fire Protection Association (NFPA), and International Standard Organization (ISO) have also defined appropriate standards for EV, HEV, and vehicle charging systems. The Infrastructure Working Council (IWC) has played a significant role in defining the infrastructure and its associated standards. International and domestic coordination exists between these standards setting organizations.

The In-Vehicle Safety Subworking Group should continue to gain an understanding of the status of developments in these items and what else needs to be done.

In the reclamation and recycling arena, the takeoff curve for advanced batteries is slow and uncertain at this point. For the next few yeas, reclamation and recycling will be mainly focused on the small batteries for consumer electronics.

With only a few thousand vehicles anticipated in the next few years, very few EV batteries are expected for recycling. They will be mainly lead acid and nickel metal hydride. The lead acid batteries can be recycled now. It may be more practical to store the nickel metal hydride batteries for disposal, or to use a basic recycling process that is available now.

In the short term, there are no significant problems. But an efficient and effective recycling infrastructure may take a few years to build. Technically, reclamation can be done now. Investment in more economically efficient processes that actually recycle the materials back into new batteries will come when the market justifies that level of investment.

Briefing on Subworking Group Agendas

Introduction
Carol Hammel
Chairperson, ABRWG

Carol Hammel introduced the session by sequentially introducing the Subworking Group chairs.

Gary Henriksen, Chair, Shipping Subworking Group

Gary Henriksen started with a status summary of existing battery shipping regulations, and reviewed the amended UN Recommendations for lithium batteries issued in mid-1999. The amendments will become effective on January 1, 2001.

After reviewing the action items from the February 1999 Shipping Subworking Group meeting, he emphasized that the Subworking Group's activities in 1999 included review of the Canadian information papers and a detailed review of the INF.7. He reported on the status of INF.7, which proposes changes to the amended UN recommendations with respect to consumer-sized lithium batteries. He then described the planned activities for the Subworking Group during this meeting.

Rudy Jungst, Chair, Recycling/Reclamation Subworking Group

Rudy Jungst stated that the goal of the Recycling/Reclamation Subworking Group is "to ensure that a cost effective means exists for the collection and reclamation/recycle of electric vehicle batteries at end-of-life." The Group's areas of interest include:

- status of reclamation/recycle process development for various EV batteries and their timetables;
- the potential for recycling materials from used batteries;
- regulatory and legislative issues;
- cost and infrastructures of battery recycling;
- industry experience in handling and recycling hazardous materials; and
- vehicle recycling approaches.

Rudy noted some major issues in the recycling of lithium-ion, lithium polymer, and NiMH batteries, including regulatory initiatives. He said that there are only a few constituents in lithium-ion batteries; that lithium can be recovered; and that research on

new cathode materials is an important issue. He then briefly explained the Subworking Group's agenda

Q: Is the Subworking Group involved in looking at the secondary use of the materials from recycled batteries?
A: Yes. We understand that USABC and Electric Power Research Institute (EPRI) are doing some testing. Utilities indicate some interest.

George Cole, Chair, In-Vehicle Safety Subworking Group

George Cole discussed the purpose of the In-Vehicle Safety Subworking Group and explained the activities. Most of the information provided by the auto manufacturers are "informal information exchanges." They are not to be treated as official positions of their respective organizations and entities. He then presented the group's planned activities for the breakout sessions in this meeting.

General Session Program I: Battery Readiness Field Experience and Battery Update

Introduction
Carol Hammel
Chairperson, ABRWG

Carol Hammel introduced the general session. She stated that the purpose of the program is to have those OEMs involved in advanced vehicles, and those who are involved in getting advanced batteries to the market, discuss what they have been doing, what they have encountered, and how they have addressed the issues. She then introduced the presenters in turn.

"DaimlerChrysler Epic Program"
George Shishkovsky
DaimlerChrysler Corporation

George Shishkovsky reviewed the CARB ZEV requirements: 2% of total new vehicle sales in California in 1998-2000 must be ZEV; 5% for 2001-02; and 10% after 2003. Chrysler started developing EVs in 1989. During 1993-95, 56 TEVan were produced. TEVan used direct current (DC) motor, and nickel iron (NiFe) or nickel cadium (NiCd) batteries. NiFe batteries were trucked from Joplin, Missouri. NiCd batteries were manufactured by SAFT and air-shipped from France. Watering and gas management systems were included.

In 1997, the EPIC was introduced. It has a Dodge Caravan body. It has an alternating current (AC) motor and uses 336V, SAFT NiMH batteries. The battery requires 6-8 hours of charging, which complies with the less than 8 hours requirement of EV America. Other performance characteristics of the EPIC: Driving range: city, 91.4 miles; highways, 97.3; combined 96.4. It accelerates from 0 to 60 mph in 17 seconds and has a top speed

of 80 mph. There are two 12-volt modules of batteries (equal to about 25 volts). During 1997-99, 234 EPIC's are produced, 189 of them are in California.

Two specific experiences with EPIC are noted here. During the 1999 North America Electric Vehicles & Infrastructure (NAEVI) show, one EPIC accumulated 350 miles in 10 hours shuttling between downtown Atlanta and the airport. There are 20 EPIC in use as an express shuttle in the LA International Airport.

The SAFT batteries are shipped to the U.S. by air from France in U.N. certified crates, passing through the customs, where some difficulties were encountered.

Q: How is DaimlerChrysler servicing the battery packs?
A: There is a SAFT dealer in LA, who stocks the battery packs. When the need for a replacement battery pack arises, we call the dealer to place an order. In California, DaimlerChrysler has trained dealer personnel who can handle battery packs safely.

"Nissan's Altra EV and Battery Recycling; Update,"
Gary Roque
Nissan North America
David Miller
Toxco

Gary Roque first noted that there is a disparity in the projections of the number of EVs in the U.S. in the coming years. In 2005, DOE estimates 320,000 EVs, compared to CARB's 50,000 a year. He stated that the Nissan Altra is a full sized van that can easily transport a family of four plus a sheep dog. The 800-pound battery pack is placed under the floor to minimize impact-related damages to the battery. There is a high-voltage power source circuit breaker. Initially, the battery is lead acid; later lithium-ion or lithium polymer batteries may be installed. Currently, Sony's cobalt-based battery is being used. However, Hitachi's manganese-based system is being considered as an alternative.

The car can accelerate from zero to 50 mph in 12 seconds; it has a top speed of 75 mph. The maximum range is 120 miles. There are about 90 Altra EV in California, including one owned by the Rogue family. Gary also stated that Nissan is developing a series of alternative fuel vehicles for the worldwide market, including the Hyper-mini, a hybrid electric vehicle. Nissan's environmental efforts is part of a global program called "Symbiosis," which is Nissan's commitment toward the harmonious coexistence of people, automobiles, and nature.

Dave Miller discussed Toxco's EV battery recycling with Nissan. Essentially, Nissan has contracted with Toxco for a share of Toxco's long range spent battery processing capacity. Toxco has agreed to provide additional capacity in California as large numbers of Nissan EVs are introduced on the California highways. Toxco will manage the Nissan

EV batteries from their facility through the recycling of the batteries. Such management includes maintaining accountability, consolidating the batteries for cost-efficient transportation, safely storing and processing spent batteries, and supplying appropriate recycling documentation.

Toxco currently recycles lithium ion batteries at its facility in British Columbia, Canada. During 1999, the company recycled close to 2 million pounds of lithium batteries. Its current production capacity is about 250,000 pounds per month. Toxco also has a new universal waste facility in Ohio that handles classification and consolidation of all types of batteries from the Mid-west and Eastern states. Toxco also teamed with Kinsbursky Brothers Inc. (KBI), adding to national and international consolidation and processing capabilities for all types of batteries.

Q: How would Nissan service and repair spent batteries?
A: It is similar to the approach adopted by DaimlerChrysler. Battery handling will be controlled. Batteries collected from the field will be sent to the Company's British Columbia plant for processing.

Q: What is cycle life for batteries?
A: Over 1000 cycles for both lithium-ion and NiMH batteries. Range for manganese system is projected to be close to that of cobalt.

Q: What are the cost implications for manganese system compared to cobalt system?
A: Manganese itself as a material is 5 to 6 times less expensive than cobalt. This will influence the cost of the batteries.

Q: How is Nissan shipping the batteries to U.S. from Japan?
A: Nissan is shipping by boat. It is much easier than shipping by plane. Batteries shipped by boat must have at least 20% of state of charge (SOC). SOC is one specification outlined in an agreement with national and international entities.

Q: At which rate of charge are NiMH batteies being shipped?
A: SAFT NiMH batteries are intially shipped at 80% SOC. Ovonics NiMH batteries are shipped 50% SOC.

"Recycling Capabilities for EV Batteries: Update"
David Miller
Toxco, Inc.
Todd Coy
Kinsbursky Brothers, Inc. (KBI)

David Miller discussed the teaming approach adopted by Toxco and KBI, battery information, and their unique process of recycling spent batteries. The teaming approach allows the companies to offer "total end of life battery management and recycling." Many different types of batteries are being used for EVs and HEVs. In the short term, it

is lead acid. In the intermediate term, it is NiMH. In the long term, there will be lithium polymer/ion and fuel cells.

The Toxco-KBI approach consolidates and recycles all types and sizes of batteries and eliminates duplicate efforts and cost. The Toxco-KBI team's battery recycling goals include safety, efficiency, re-utilization of materials, cost-effectiveness, and environmentally "green." The recycling process is composed of the following steps: cryogenic freezing to about minus 190 degrees C; under water (solution) breach of case; electrolyte/lithium neutralized; material separation; and recovery of lithium, metals, and cobalt. Toxco also has a facility in Ohio that handles universal wastes, including battery classification and identification. The Ohio facility offers transport and logistics services, individualized customer support services. In late 2000, it will also be able to process nickel and lead.

KBI's total battery management approach was discussed, including the types of materials recovered; case metals – ferrous and non ferrous, lithium, nickel, cobalt, and some plastics. Mr. Miller also went over the results of 1999 operations, combining the two companies. Working directly with recycling facilities can lower the cost of recycling.

The Toxco-KBI team believes that the use of EV and HEV will increase dramatically in the next 5 years. This would happen mainly in California, followed closely by some states in the East Coast and the Midwest. They further believe that the principal battery types for the next 10 years will be nickel or lithium based.

Q: What is the status of recycling lead acid batteries?
A: Recycling lead acid batteries is profitable. The recyclers collect a fee for taking the used batteries from consumers and they generate revenues from selling the reclaimed materials.

Q: Toxco's lithium thionyl chloride recycling process is water-compatible. Are there any changes needed to Toxco's process for organic-based lithium ion batteries?
A: Most organics are burned off at the surface of the caustic bath. Toxco will develop new technologies for addressing new challenges.

"Ford NiMH Ranger: Field Experience"
Ted Miller
Ford Motor Company

Ted Miller reviewed the field experience of Ford Rangers equipped with NiMH batteries. By the end of 1999, there were about 1000 Ford EV, 350 of which equipped with NiMH batteries. By the end of 2000, there will be 1300 Ford EV in the field, with about 650 equipped with NiMH batteries. Qualified technicians at authorized Ford dealerships will handle EV batteries, conduct detailed or unique battery and module diagnosis, and module failure analysis. There are a total of 45 dealers in 24 states with qualified

technicians. They will be equipped with special battery service tools such as EV battery module charger. Standard commercial 12V chargers could not be sufficiently modified for use with NiMH batteries. So a special 12V charger had to be developed for use in charging NiMH batteries.

With lead acid batteries, 8V VRLA modules are manufactured by East Penn in Pennsylvania and are fully recycled there. Lead, plastic cases, and electrolyte are reclaimed and used for new batteries. Sulfur fumes are trapped during lead smelting and used in the production of fertilizer.

NiMH batteries are 12V modules manufactured by Panasonic EV Energy (PEVE) in Japan. In the U.S., recycling of NiMH batteries is done by INMETCO in Pennsylvania. Plastics are classified and recycled. Free electrolyte is utilized as a pH control reagent in wastewater treatment plant. Internal cell components are fed into a rotory furnace. Nickel-chromium-iron remelt alloy pigs are used in stainless steel manufacturing. Other than shipping, the recycling process is cost-neutral.

Q: Do you have a NiMH battery recycling facility in the West Coast?
A: No, we don't.

"New Developments with the Lithium Ion Battery"
Dr. Noboru Arai
LIBES, Japan

Dr. Noboru Arai reported on the development of large-scale lithium ion battery technology in the Japanese National Program conducted by the Lithium Battery Energy Storage Technology Research Association (LIBES). LIBES has 13 members. Its objectives are to contribute to load leveling using night rate electricity and to reduce GHG by developing high-performance and large-scale Lithium ion batteries. These include 2 stationary types and 2 pure EV application types. The program period is from FY 1992 through FY 2001. The research and development work of LIBES focuses on three areas: development of module battery, development of next generation battery technology, and studies on battery total systems. In battery module development, work is being conducted on stationary types, EV application types, carbon materials, and battery safety technology. With respect to next generation battery technology, the emphasis is on lithium polymer battery, lithium metal battery, and non-flammable electrolyte. On studies on total battery systems, system analysis and design, and safety evaluation are being pursued. In addition, efforts are also being directed at further improving the performance of cathode materials, anode materials, cell manufacturing technology, and module structure optimization.

Dr. Arai provided a summary of the target and results to date for the large-scale module for EV application type:

EV Application Type	Battery System	Ni-Co	Mn
	Cell Shape	Elliptic Cylindrical	Cylindrical
	R&D Target	Test Results	Test Results
Capacity (kWh)	3	3.55	3.17
Specific Energy (Wh/kg)	150	143	109
Energy Density (Wh/L)	300	230	199
Specific Power (W/kg)	400	592	416
Energy Efficiency (%)	85	96.4	96.6
Cycle Life (Cycle)	1000	>600 (900)	(>400)

Note: Value in ( ) of cycle life is estimated value obtained by cell cycle test carried out by each responsible company.

Similarly, there is also a summary of the target and result to date for the large-scale module for stationary type batteries:

Stationary Type	Battery System	Ni-Co	Mn
	Cell Shape	Cylindrical	Prismatic
	R&D Target	Test Results	Test Results
Capacity (kWh)	2	2.14	2.04
Specific Energy (Wh/kg)	120	116	101
Energy Density (Wh/L)	240	174	214
Energy Efficiency (%)	90	96.7	97.3
Cycle Life (Cycle)	3500	(2000)	(1000~1500)

Note: Value in ( ) of cycle life is estimated value obtained by cell cycle test carried out by each responsible company.

Dr. Arai further discussed LIBES work on mid-sized batteries for both mobile and stationary applications such as small commuter cars, scooters, refrigerators, home-use energy storage systems, and eco-lights. Future work at LIBES will focus on three areas: (1) Achieving the targets for the battery module performance in terms of energy density and cycle life. (2) Developing mid-scale battery systems for early commercialization, including battery management system, thermal management system, and safety management system. (3) Resolving the issues for commercialization in the areas of battery safety, and battery cost.

Q: In addition to the performance targets, are there cost targets?
A: Battery cost is one issue to be addressed in the future work of LIBES.

"SAFT EV/HEV Battery Field Experience"
Dr. Salah Oweis
SAFT R&D Center

(Salah Oweis was unable to make the presentation during the meeting. However, he indicated that he would make the presentation materials available for inclusion in the Executive Summary Supplement.)

General Session II
Carol Hammel
Chairperson, ABRWG

Carol Hammel opened the second general session and introduced the Subworking Group Chairs.

Subworking Group Activity Reports and Meeting Summaries

Gary Henriksen, Chair, Shipping Subworking Group (SSWG)

Mr. Gary Henriksen summarized the Shipping Subworking Group as follows:

Attendance

Attendee	Organization	Telephone Number
E. (Andy) Altemos	HMT Associates, LLC	(202) 463-3511
Ralph Brodd	Broddarp of Nevada	(702) 897-3927
Benoit Chasse	Argo Tech Productions	(450) 655-3161
Victoria Gellis	Capital Environmental	(202) 383-6840
Ahsan Habib	GM	(248) 680-5946
Carol Hammel	NREL	(202) 651-7520
Gary Henriksen	ANL	(630) 252-4591
Charles Ke	RSPA/DOT	(202) 366-4495
Charles Monahan	Panasonic	(201) 392-6464
Russ Moy	USDOC/Ford	(202) 482-6266
Noriko Shioda	LIBES	81-3-5951-1021

Agenda

March 22, 2000

- Distribute Canadian information paper (INF. 7)
- Distribute SSWG consensus comments on INF. 7
- Summarize UN Working Group meeting of March 13-15

- Distribute and discuss USDOT "draft" proposal

March 23, 2000

- Provide initial feedback to USDOT on "draft" proposal
- Develop list of unresolved issues and action items

Meeting Summary

Dating back to 1998, there has been an effort to modify the tests that are used to qualify lithium battery designs safe for transport. These tests are described in the UN "Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria." For more than a year, Canada has been leading this effort by generating numerous versions of information papers, several of which were submitted for consideration by either the UN Sub-Committee of Experts (July and December 1999) or the UN Committee of Experts (December 1998). As described in the summary of our February 1999 meeting, the USDOT requested that the SSWG assist them by reviewing and commenting on these papers for the purpose of ensuring that the provisions of the modified tests are relevant for large (EV and HEV size) lithium cells and batteries. The USDOT also expressed its desire to have a common set of tests and test procedures for both small and large cells and batteries, if possible.

The latest version of the Canadian information paper (INF.7) was submitted for consideration by the UN Sub-Committee of Experts at its December 1999 meeting. At that meeting, it was decided that an UN Working Group should be established to study this issue and to develop a proposal for consideration by the UN Sub-Committee of Experts at their July 2000 meeting. INF. 7 was to be used as the basis for the proposal. In January 2000, USDOT requested that the SSWG conduct a detailed review of INF. 7 and provide them with a set of consensus comments prior to a UN Working Group meeting that was scheduled for mid-March in Ottawa, Canada.

The SSWG chairman distributed copies of INF.7 to Argo Tech, Delphi, Eagle-Picher, PolyStor, and SAFT America with the request that they review the paper and respond with their comments prior to a special meeting of the SSWG, scheduled for February 17, 2000, at the Washington, DC, office of Argonne National Laboratory. Written comments were received from Argo Tech, Eagle-Picher, and PolyStor. The February 17, 2000, meeting was conducted for the purpose of developing a set of consensus comments on INF. 7. It was attended by representatives from Argo Tech and SAFT America, as well as ANL, NREL, and HMT Associates. A written set of consensus comments were developed and submitted to the USDOT on March 1, 2000.

At the beginning of this year's SSWG breakout meeting, the chairman distributed additional copies of INF. 7 and the SSWG consensus comments to the attendees. He then inquired if there was any desire or need to discuss these two documents in light of the fact that a new "draft" proposal had been developed by the USDOT. Charlie Ke (USDOT) commented that their proposal was based on INF. 7 and that they had considered the SSWG comments when they developed their "draft" proposal. He

commented further that the USDOT "draft" proposal was distributed at the UN Working Group meeting (March 13-15, 2000) and was used as the basis for discussions at that meeting. It was decided to skip discussion of INF. 7 and the SSWG consensus comments on INF. 7 and move directly to the summary of the UN Working Group meeting. Charlie provided a brief synopsis of what transpired at the meeting, focusing on the USDOT position and philosophy used in developing their "draft" proposal. He mentioned that by the end of the meeting, there was general agreement on the first five tests (Tests 1 through 5), both in terms of their relevance to shipping and the detailed test procedures. In some cases the procedures were modified over what appeared in INF. 7, but they are based on the first five tests in INF.7. The UN Working Group could not agree on the relevance or the test procedures for Test 6 Internal Short Circuit. Although there was not consensus agreement on the relevance of Tests 7 and 8, the UN Working Group did agree on procedures for these tests, should they be judged relevant for transportation.

Next, Charlie distributed a slightly revised version of the USDOT "draft" proposal, which contained the changes made as a result of the UN Working Group meeting. A copy is provided as Appendix A. (Appendix A will be included in the Executive Summary Supplement.) He proceeded to provide a brief description of its content. There was some preliminary discussion of the document, both in terms of the USDOT position and in terms of the document's content. The meeting was adjourned at the break, to allow the attendees to review the "draft" proposal in more detail on their own, with the objective of providing Charlie with some preliminary feedback when we reconvened on the morning of the following day.

When the SSWG reconvened, several meeting participants provided comments and asked questions about the content of the "draft" proposal. A major point of clarification was that the "draft" document actually proposed three categories of lithium cells and batteries:

- Very small cells and batteries, with a maximum of five per package, could be shipped unregulated, after they passed the design qualification tests.
- Slightly larger cells and batteries, with a maximum of five per package, could be shipped without using the Packing Group II specified packaging and (when shipped by ground transport) without the "Lithium Battery" Class 9 labeling, after they passed the design qualification tests.
- All other lithium cells and batteries would be shipped subject to all of the UN Class 9 shipping requirements, after they passed the design qualification tests.

The limits on the lithium content of cells, batteries, and packages for categories 1 and 2 are provided in Appendix A. A new feature of this proposal is that even the category 1 cells and batteries are required to pass the design qualification tests.

Another major issue was the required testing of battery modules and battery assemblies (battery packs). For many applications, including the EV and HEV applications, full-scale batteries are often comprised of battery modules, which are the basic building blocks. Manufacturers may want to transport individual battery modules, as well as the full-scale batteries (referred to here as battery assemblies). Significant discussion was

held on the need for conducting the design qualification tests on battery assemblies, if the battery modules had already been subjected to these tests and passed. Andy Altemos recommended a compromise, which involved the manufacturer making a determination (either by actual testing or by other appropriate means) that the battery assemblies, as shipped, would be capable of passing the non-destructive tests (Tests 1-5). This remained an unresolved issue at the end of the meeting, however, Charlie Ke appeared willing to consider Andy's recommendation. Following the meeting, Andy recommended the following wording to handle this situation:

Recommended Wording
for
Testing Battery Assemblies

Add a new (f) in paragraph 38.3.3 to read:

"(f) When large batteries having passed all applicable tests in accordance with (a) through (e) above are offered for transport electrically connected to form a battery assembly, the battery assembly must be capable of passing Tests 1 through 5."

Under the conditions specified in the USDOT "draft" proposal, the minimum quantities of cells and/or batteries required to conduct the design qualification tests are listed in the following table.

Test	Quantity of Cells	Quantity of Batteries
Tests 1 through 5	20	8
Test 6	5	0
Test 7	0	8
Test 8	20	0
Total for all Tests 1-8	45	16

There was some discussion on the issue of the batteries that had already been subjected to Tests 1-5 as being appropriate for use as the tested batteries in Test 7, if they were not damaged in Test 5. This would reduce the total quantity of batteries to 12. This becomes a real issue for large (EV and HEV) batteries, due to their high cost.

The action items from the SSWG breakout meeting deal primarily with the unresolved issues. They are listed below:

Action Items for 2000

- Work with USDOT on the relevance of Tests 6-8 to determine if they are relevant for transportation. If Test 6 is determined to be relevant, assist in obtaining a consensus on the test procedure.
- Work with USDOT to establish an appropriate way of dealing with battery assemblies.
- Work with USDOT to minimize the number of large batteries needed to qualify them safe for transport, without compromising safety in transport.
- Review and comment on future versions of the USDOT proposal.

Rudy Jungst, Chair, Recycling/Reclamation Subworking Group

Mr. Rudy Jungst provided the following highlights of the deliberations of the Recycling/Reclamation Subworking Group:

Attendance

Attendee	Organization	Telephone Number
Morris Altschuler	EVA/DC	301-770-5591
James A. Barnes	DOE	202-586-5657
Joseph C. Calio, III	LithiumTechnology Corp.	610-940-6090
Helen Cost	DaimlerChrysler	248-833-5327
Francois Cardarelli	ARGOTECH (HQ)	450-655-3161x243
Debbie Elcock	ANL	202-488-2451
Tom Evashenk	CARB	916-445-8811
Jeff Fang	NREL	202-651-7515
Linda Gaines	ANL	630-252-4919
Paul Gifford	GM Ovonic	248-637-7440
Gewis Gulick	EV News	703-276-9093
Ian Graig	Global Policy Group	202-496-1550
Carol Hammel	NREL	202-651-7520
Albert Himy	Navy/JJMA	703-418-4257
Sanghee Hong	GM	317-579-3702
Toru Iwahori	CRIEPI	81-3-3480-2111
Wade Jordan	Coastal Management	252-482-7996
Rudy Jungst	Sandia	505-844-1103
Joseph Kejha	Lithium Technologies	610-940-6090x111
Peter Kuck	USGS	703-648-4965
Dale Larson	Mitsubishi Research	202-785-2424
John Lippert	EVA/DC ECO-Living, Inc.	301-345-5324
Brian McTiernan	Crucible Research Center	412-923-2955x232
David Miller	Toxco	714-630-8378

Jeff Molander	SMUD	916-732-6350
Ken Money	INMETCO	724-758-2808
Saskia Mooney	Capital Environment	202-383-7350
Russel Moy	DOC	202-482-6266
Joyce Ober	USGS	703-648-7717
Richard M. Prouty	EVA/DC	301-464-8306
David A. Thompson	Panasonic	201-271-3486
Seiji Yamaguchi	Panasonic	248-447-7101

Agenda

March 22, 2000

1:30 *California ZEV Program Update* - Tom Evashenk, California Air Resources Board
2:00 *EV Battery Recycling Infrastructure Issues* - Todd Coy, Kinsbursky Bros.
2:15 *Battery Recycling and Life Cycle Costs* - Linda Gaines, Argonne
2:45 *Recycling of Nickel Bearing Scrap* - Peter Kuck, US Geological Survey
3:00 *Lithium Market/Supply News* - Joyce Ober, US Geological Survey
3:15 Break
3:30 *Battery Recycling at INMETCO* - Ken Money, INMETCO
4:00 *HPS - High Purity Lithium from Spent Lithium Battery Materials* - Joe Kejha, Lithium Technologies
4:30 *Lithium Battery Recycling by Sony* - Doug Smith, Sony

March 23, 2000

8:00 *EV Battery Recycling* - David Miller, Toxco
8:30 *Ni/MH Battery Recycling Status and Needs* - Rudy Jungst, Sandia
9:00 *Lithium Battery Recycling Status and Needs* - Rudy Jungst, Sandia
9:30 *Recycling Readiness Chart Update and New Action Items* - All
10:15 Break

Highlights

An update on the California ZEV program was presented. The next review of the program will occur in September 2000 but it will not be a regulatory review. This means that no changes will be made to the program at that time. The current EV population in California totals approximately 2000 and a projected market of 22,000 true EVs will be needed to meet the year 2003 requirements currently in place.

California rules for handling hazardous waste were also discussed. In some cases, the California requirements are more stringent than Federal regulations. An emergency Universal Waste Rule has very recently been adopted on an interim basis in California in order to provide a single standard. It was pointed out that damaged batteries would be considered a hazardous waste and not a universal waste in some cases.

Information on recycling and life cycle costs was presented for the nickel/metal hydride and lithium-ion battery systems. Recycling economics usually favors recovering

materials in as close to the original use form as possible. For AB_2 type Ni/MH batteries, the value is in the nickel and in the metal hydride alloy. In the Li-ion case, the cathode is responsible for most of the value, unless a manganese oxide cathode is used. The electrolyte, particularly the salt, is another potential source of value for Li-ion batteries.

Prices and market trends for some of the more important battery materials were reviewed. Nickel prices are currently up significantly from recent levels. Commodity recycling flow diagrams are being developed by the US Geological Survey for several metals, including nickel. Approximately 6000 tons of slightly radioactive nickel are in storage and available for reuse, if a suitable application for it can be found. A facility in Argentina that was scheduled to open last year for the production of lithium from a brine source is now permanently closed. Production cuts for lithium are also rumored in Russia and China. However, lithium prices have remained relatively stable.

The operation of the INMETCO battery recycling capability was described. Expansion of the cadmium recovery facility at INMETCO has increased capacity by 75% for recovery of that material. The complex set of factors that governs recycling economics was discussed. Some battery disassembly can be supported by the economics, particularly for large cells.

Lithium Technologies and Pacific Lithium Ltd. will merge into one company later this year. A membrane process that has been developed by Pacific Lithium to purify lithium recovered from scrap batteries was discussed. The process currently operates on a laboratory scale in a batch mode, and an energy study projects that it will be cost effective.

The entire Sub-Working Group discussed the status and future needs for comprehensive recycling of nickel/metal hydride and lithium-ion batteries. Reuse of components from nickel/metal hydride cells, although attractive from a recycled value standpoint, was viewed as unlikely to occur because of difficulty and high cost involved in refurbishment of worn out batteries. It was suggested that it would be preferred to recycle metal hydride alloys through the alloy manufacturer since it is believed that some remelt can likely be tolerated in the process. However, the effect of impurities accumulated in the materials during use of the battery and the amount of recycled material that can be incorporated in the process without degrading the final product are unknowns at this point. Some battery sorting and disassembly is probably desirable and can be supported for high numbers of relatively large batteries.

Most of the discussion about recycling the lithium-ion battery system revolved around the cathode material. Although the value of cobalt is sufficient to make its recovery economically justifiable, alternative metals such as nickel and manganese that may be used in cathodes have lower value. More information is needed regarding the value of manganese oxide and potential markets for it as well as the recovery cost so that a break-even point can be estimated. Fluctuation in metal prices could possibly cause the recycling cost of even cobalt and nickel to exceed the value of the recovered product. The recovery and purification of electrolyte salt from lithium-ion batteries versus

remanufacture of the salt from lithium carbonate was also discussed briefly. Processing cost is again uncertain, but it appears that purification could be complicated and therefore too costly. Processes for recycling lithium-polymer batteries are being developed, but the details are considered proprietary at the present time. A renewed effort should be made to obtain information in this area.

Action Items for 2000

- Reinforce efforts to obtain information on battery collection and recycling procedures in Europe and Japan.

- Evaluate the influence of HEV introductions on the EV/HEV population and recycling needs.

- Request updates and reports on other lithium-ion and lithium-polymer battery recycling approaches that are being developed.

- Continue to request information on EPA solid waste definition projects.

- Obtain information on hydride alloy properties, impurity tolerance, and potential markets for reclaimed material. Some electrode analysis may be needed.

- Collect information about markets for recycled rare earth materials.

- Define the cost of cathode and electrolyte material recovery from the lithium-ion battery system more clearly.

George Cole, Chair, In-Vehicle Safety Subworking Group

George Cole provided the following summary:

Attendance

Attendee	Organization	Telephone Number
Noboru Arai	LIBES	3-5951-1021
George Cole	INEEL	208-526-9471
William Evans	US DOT/NHTSA	202-366-5395
David Goldstein	EVA/DC	301-869-4954
Carol Hammel	NREL	202-651-7520
Kenneth Heitner	US DOE	202-586-2341
Barbara Hennessey	US DOT/NHTSA	202-366-4714
Ray Hobbs	Arizona Public Service Co.	602-250-1510
Charles Hott	NHTSA	202-366-0247
Ruth MacDougall	SMUD	916-732-6625

Robert Minck	Ford	313-248-5924
Ahmed Pesaran	NREL	303-275-4441
Jerry Pierson	DaimlerChrysler	248-944-2718
Tim Sack	SAFT	410-771-3200
George Shishkovski	DaimlerChrysler	248-576-0922
David Swan	AeroVironment	626-357-9983
Jason Ting	Crucible Research	412-923-2955x201
Victor Wouk	Curtis Instrument	212-534-6757

Introduction

The nature of the In-Vehicle Safety Subworking group is such that it focuses on the following four activities:

(a) Identifying 'battery system related' in-vehicle safety concerns which might pose barriers to the successful implementation of EVs due to regulatory actions or lack of standards

(b) Evaluating the severity of such safety concerns and determining whether appropriate action is being taken by the government or industry to address them

(c) Referring significant issues to appropriate government or industry (e.g. standards making) bodies for consideration or further research (e.g. by the U.S. DOE) where needed; and

(d) Tracking progress on the resolution of identified safety concerns

The Subworking group is an informal information exchange forum, and no participant's remarks are to be construed to be an official statement or position representing his or her employer. In keeping with this intention, specific statements are often deliberately not attributed to particular individuals in these minutes.

After introductions of the attendees, the agenda was reviewed. The agreed upon agenda is as follows:

Agenda

Wednesday March 22, 2000 1:30 – 5:00 PM

- Introductions
- Old Business
  - Status of Notice of Proposed Rulemaking FMVSS 305
  - Update on NHTSA/DOE accident investigations
  - Results of NHTSA EV Crash Tests
  - Battery Abuse Testing
  - Update on international standards making activities

USABC/LIBES/USDOE/MITI cooperation

- New Business
  - Battery gassing and potential for gasses to enter the passenger compartment
  - Establishment of field experience database
  - Need for EV Design Guidelines or Code of Practice
- Open discussion
  - Member experience based issues
  - Member experience with abuse testing
  - Other

Thursday March 23, 2000 8:00 – 10:00 AM

- Continuation/wrap-up of previous day's discussions
  - Assignment of action items
  - Preparation of sub-working group summary

Summary

Status of Notice of Proposed Rulemaking FMVSS 305

The Subworking group is tracking the progress of the proposed Federal Motor Vehicle Safety Standard (FMVSS) 305. The Notice of Proposed Rulemaking appeared in the Federal Register on October 13, 1998 (Federal Register, Vol. 63, No. 197, Pages 54652 – 54660). The proposed safety standard would establish requirements and test procedures which address safety issues exclusive to electric vehicles: Electrolyte spillage, post-crash retention of batteries in their mounts, and shock hazard. The proposed standard is based upon SAE J1766 FEB96 "Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing" and would be known as "Electric-powered vehicles: electrolyte spillage and electrical shock protection". Test procedures would include the frontal barrier crash test of Standard No. 208, the side moving barrier crash tests of Standard No. 214, and the rollover and rear moving barrier crash tests of Standard No. 301. However, as proposed, the standard would not apply to low-speed electric vehicles regulated by Standard No. 500.

Representatives of the Department of Transportation (DOT), NHTSA could not provide any specific information regarding the progress of this rulemaking activity. The proposed rule is following the normal regulatory course and a final determination on this specific rule should be made in the next few months.

Update on NHTSA/DOE accident investigations

At the 1997 meeting this Subworking group recommended that the DOE take action to gather information regarding safety-related incidents involving electric vehicles. Since that meeting, the USDOE determined to sponsor a limited program of accident investigations through NHTSA's Office of Special Crash Investigations. Subsequently, a

Memorandum of Understanding (MOU) between the USDOE and NHTSA was implemented for the conduct of this work. The project makes use of NHTSA's standard accident investigation process, with a focus on accidents or incidents that appear to contain elements of special interest with respect to electric vehicles; for example, those where battery leakage or electrical shock are encountered would have high significance.

William Evans (DOT-NHTSA) reported on the status of this project. To date, only one incident involving an electric vehicle has been reported to NHTSA for investigation. The status of the resulting investigation was reported at the February 1999 Subworking Group meeting. The report on this investigation has not yet been released. Mr. Evans stated that one issue hampering investigations is that it is not apparent that accidents and incidents are routinely reported to NHTSA for investigation. His office stands ready and willing to investigate accidents when they are reported to NHTSA. Notification of incidents is usually reported to NHTSA through law enforcement agencies. However, NHTSA will accept notification from any party. Mr. Evans felt the problem of not reporting accidents to NHTSA was mainly due to organizations being unaware of reporting needs and the simple reporting process and stated that NHTSA will be making an extra effort in the coming months to make EV users aware of this project. NHTSA may be notified by FAX (202) 366-5374, toll free voice telephone (877) 201-3173, email (william.evans@nhtsa.dot.gov) or mail (400 Seventh Street, SW, Washington, D. C. 20590). Notification forms were passed out (see Executive Summary Supplement [April 2000]) to participants to distribute to appropriate people within individual's organizations. It was noted that the USDOE Field Operations Program (FOP) involves approximately 10% of all EVs in the US and George Cole agreed to provide NHTSA reporting form to the USDOE FOP Program Manager for distribution to EV fleets in the FOP.

Mr. Evans requested information and/or training materials that may be available for first responders (e.g. fire departments, Emergency Medical Technicians), as this information would be useful training material for NHTSA accident investigators. It was recollected that the USDOE sponsored (at least in part) the development of training programs for accident responders. Kenneth Heitner and George Cole agreed to research the existence of this material and provide it to William Evans if available.

Results of NHTSA EV Crash Tests (Ford Ranger, EV1)

It was noted that NHTSA conducted recent crash tests on some EVs and NHTSA representatives were asked to comment on the results of these tests. Within the last year (approximately) crash tests were performed on a Ford Ranger pickup truck, a General Motors EV1, and a Honda Insight hybrid-electric vehicle. These tests were performed as part of NHTSA's New Car Assessment Program and were not compliance tests. The main difference between the tests in these two programs is the vehicle speed upon impact with the barrier. Impact speed in the New Car Assessment program is 35 mph but only 30 mph for compliance tests. The Ford Ranger and the GM EV1 were tested in 1999. The Honda Insight was recently tested and the results were unavailable at this time. Both

the Ford Ranger and GM EV1 received at least a 3-star rating. Details of the results are posted on the Internet as follows:

1999 Ford EV Ranger	http://www.nhtsa.dot.gov/cars/testing/ncap/cars/821.html
1998 GM EV1 2DR	http://www.nhtsa.dot.gov/cars/testing/ncap/cars/686.html
2000 Honda Insight 2DR (Results due March 2000)	http://www.nhtsa.dot.gov/cars/testing/ncap/cars/1514.html

Note: Results of all of NHTSA's New Car Assessment Program tests can be found via their customized search page at http://www.nhtsa.dot.gov/cars/testing/ncap/.

NHTSA representatives noted that due to the unique hazards associated with electric and hybrid-electric vehicles that the proposed FMVSS 305 allowed crash tests to be conducted in a safer manner.

Battery Abuse Testing

Since the previous meeting of the Subworking group, battery abuse test procedures were published in a report for the USABC and as an SAE document. During the meeting, the battery abuse tests of recommended practice SAE J2464 "Electric Vehicle Battery Abuse Testing" were summarily reviewed for their applicability for testing hybrid-electric vehicle batteries. These tests are routinely used within the USDOE hybrid-electric vehicle development programs and as a result have been de facto applied to hybrid-electric vehicle batteries. After a short discussion it was noted that at least some of the particular test parameters described by the recommended practice might not be directly applicable for hybrid-electric vehicle batteries. The particular tests mentioned were the Overcharge Test (Cell Level or Above), Overdischarge Test (Cell Level or Above), and Overheat/Thermal Runaway Test (Module Level or Above). Dr. Kenneth Heitner (USDOE) agreed to review the details of these test procedures and make recommendations to the Subworking group of any changes that may be necessary.

Update on international standards making activities

Victor Wouk provided an update to the Subworking Group of the current safety-related activities within various standards-making organizations (i.e. International Standards Organization (ISO), International Electrotechnical Commission (IEC), Society of Automotive Engineers (SAE) and the European Committee for Standardization (CEN)). Mr. Wouk's report to the sub-working group is appended to these minutes. It was noted that the ISO and CEN have just begun to consider standards for electric and hybrid-electric vehicles and will be using the documents and experiences within the IEC and SAE as a basis for their activities. Mr. Wouk was asked to investigate the possibilities of coordinating the efforts of this sub-working group and the IEC, SAE, and ISO in the area of fuel cells. At present, the charter of the Advanced Battery Readiness Ad Hoc Working Group as well as this Subworking group does not extend to fuel cells.

USABC/LIBES/USDOE/MITI cooperation

Dr. Heitner reported on the status of the cooperation between the USABC, LIBES (the Japanese lithium battery consortium), USDOE, and MITI (Ministry of Trade and Industry. LIBES and USABC, with input from EUCAR, contributed to the development of SAEJ2464, which is the technical basis for testing advanced batteries for tolerance to abuse. The group is studying if further related activities are appropriate. Dr. Heitner will continue to report back to the Subworking group on this activity.

Battery gassing and potential for gasses to enter the passenger compartment

It was noted that some electric and hybrid-electric vehicle designs circulate passenger compartment air through the vehicle battery pack as a means of battery thermal management and providing heat to the passenger compartment. This design was viewed as potentially hazardous to occupants, particularly in the case of an upset or faulty battery subsystem. It was questioned if this is a particularly sound practice possible need for any standards or recommended practices that would address the hazards and/or safety aspects of mixing passenger compartment air and air within the vehicle battery was suggested. After considerable discussion, the consensus opinion was that this practice is a cause for concern. However, there is at present insufficient information available to determine whether or not the severity warrants any Subworking group action. This topic will be taken as an unresolved safety issue and tracked by the Subworking group in the future, until such time that enough information is collected to warrant a Subworking group resolution.

Establishment of field experience database

One participant suggested an industry need for a safety-related field experience database. Such a database may include safety-related experiences and incidents and could be used to identify trends that may lead to Subworking group actions. Lessons learned from incidents could be incorporated into the database for sharing between the electric vehicle industry. It was recognized that particular organizations would consider this information to be highly sensitive. After considerable discussion, there was a feeling that much of the suggested information may already be available from several sources, including the USDOE Field Operations Program (FOP) and NHTSA's accident investigation efforts. George Cole agreed to meet with the USDOE FOP program managers and determine the content and extent of available data and report back to the Subworking group at the next meeting.

Need for EV Design Guidelines or Code of Practice

One participant suggested the industry need for a safety-related "code of practice" or "design guidelines" for electric and/or hybrid-electric vehicles. A great amount of information regarding good design practices is available from many sources including the SAE and IEC. Also, Victor Wouk reported that the ISO has essentially taken upon this effort. The Subworking group will take no further action on this topic.

Other

Subworking group participants brought up no further topics.

Action Items

Action items resulting from this meeting of the In-Vehicle Safety Subworking Group are summarized below:

1. George Cole (INEEL) and Kenneth Heitner (USDOE) will research the availability of training material for emergency first responders and provide this material to William Evans (NHTSA).

2. Subworking group participants will encourage electric and hybrid-electric vehicle fleet operators and users to report accidents involving these types of vehicles to NHTSA's Special Crash Investigations Program. Information on reporting is included in the Executive Summary Supplement (April 2000).

3. Kenneth Heitner (USDOE) will review the tests and test parameters specified in battery abuse test procedures (USABC Battery Abuse Test Procedures and Recommended Practice SAE J2464 "Electric Vehicle Battery Abuse Testing") for their applicability to hybrid-electric vehicle batteries.

4. George Cole (INEEL) will contact the USDOE FOP program manager and determine if any safety-related data or database exists, and if appropriate, notify Subworking group participants of its availability.

Closing Remarks
Carol Hammel
Chairperson, ABRWG

Carol Hammel stated that the Executive Committee would meet in the afternoon to discuss future directions for the ABRWG. The Subworking Group chairs will also hold side meetings as necessary throughout the year. Carol also mentioned the availability of the following two NREL papers:

> Hammel, C.J., Cole, G.H., Heitner, K.L., Henriksen, G., Hunt, G., & Jungst, R., "Government-Industry Partnerships and Environmental and Safety Solutions."
>
> Jungst, R.G. "Recycling of Advanced Batteries for Electric Vehicles."

The papers will be sent to those who are interested.

Dr. Ken Heitner
DOE Program Manager and Executive Committee Chairman

Dr. Ken Heitner thanked the Subworking Group chairs, Carol Hammel, and Nikki Kelly for their work for a successful meeting. The meeting was then adjourned.

Advanced Battery Readiness Ad Hoc Working Group
Executive Committee Meeting

Wyndham Washington Hotel
Washington, DC
March 23, 2000

Summary of Action Items

Action #1: Subworking Group chairs e-mail their summary, highlights, and action items to Carol by March 31, 2000. (Gary, Rudy, and George)

Action #2: Circulate an executive summary of the meeting electronically by April 6, 2000. The electronic executive summary will include the summary of the general sessions; Subworking Groups summaries and action items; and action items from the Executive Committee meeting. It will not include any detailed presentation materials. (Carol)

Action #3: Distribute in hard copy an executive summary supplement with general session presentation materials, overhead viewgraphs, and other related items, dated April, 2000. A final supplement will be distributed as soon as possible with subworking group presentation materials. (Carol)

Action #4: Check with SAE and other relevant groups to make sure there is no conflict and then pick the date for the next annual meetingmeeting for-Year 2001. The meeting will continue in the same format. (Carol)

Action #5: Continue to monitor and review the development in the Canadian information paper, INF.7 and the associated DOT rulemaking. (Gary)

Action #6: Regarding CARB's upcoming ZEV Review, call CARB contact person to request opportunity to speak at the September, 2000 review meeting on behalf of the ABRWG. (Carol)

Action #7: With respect to in-vehicle safety, review listing of SAE standards and other relevant documents, such as publications of the National Fire Protection Association, etc., and prepare one-line summaries. (George)

Action #8: Add the list of standards with one-line summaries (from Action #7) to the Battery Readiness in-vehicle safety web page. (Carol)

Action #9: Add the executive summary of this year's ABRWG annual meeting (from Action #2) to the Battery Readiness web page. (Carol)

Action #10: Update mailing list by identifying those who did not participate in this year's meeting. Send letter saying we missed you and inquire about whether they want to continue to be included in the mailing list. Phone those who do not respond but had shown interest in the past. (Carol)

Action #11: Prepares an outline of the 1994 NREL assessment update of recycling of NiMH batteries for review and comments. (Carol)

Action #12: Check with USCAR on vehicle/battery assessments. (Ken)

Action #13: Add Salvage Groups to the mailing list. (Carol)